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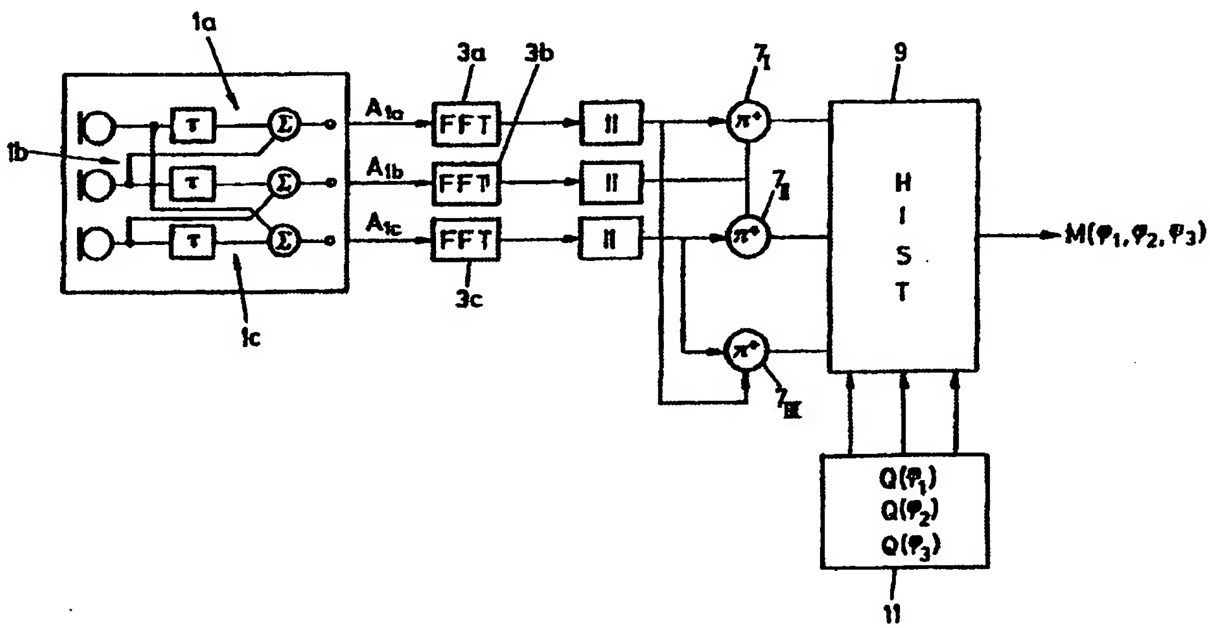
(71) Demandeur/Applicant:
PHONAK AG, CH
(72) Inventeur/Inventor:
ROECK, HANS-UELI, CH
(74) Agent: ROBIC

(54) Titre : PROCEDE DE LOCALISATION DE DIRECTION ET DISPOSITIF DE LOCALISATION
(54) Title: METHOD FOR LOCALISING DIRECTION AND LOCALISATION ARRANGEMENT



(57) Abrégé/Abstract:
The invention relates to a method for localising sources of electromagnetic or acoustic signals in relation to a sensor arrangement (1a to 1c) with at least two electrical outputs. The two transmission functions, which are dependent on the direction of incidence, are different between the acoustic signals that are incident on the sensor arrangement (1a to 1c) on the input side and the electrical output signals. According to the invention, the quotient (7_I to 7_{II}) of the output signals is formed and the result is then correlated with the previously determined quotient function (11).

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(71) Anmelder *(für alle Bestimmungsstaaten mit Ausnahme von US)*: **PHONAK AG** [CH/CH]; Laubisrütistrasse 28, CH-8712 Stäfa (CH).

(72) Erfinder; und
(75) Erfinder/Anmelder *(nur für US)*: **ROECK, Hans-Ueli** [CH/CH]; Heusserstrasse 27, CH-8634 Hombrechtikon (CH).

(74) Anwalt: TROESCH SCHEIDEGGER WERNER AG; Schwäntenmos 14, CH-8126 Zumikon (CH).

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(54) Title: METHOD FOR LOCALISING DIRECTION AND LOCALISATION ARRANGEMENT

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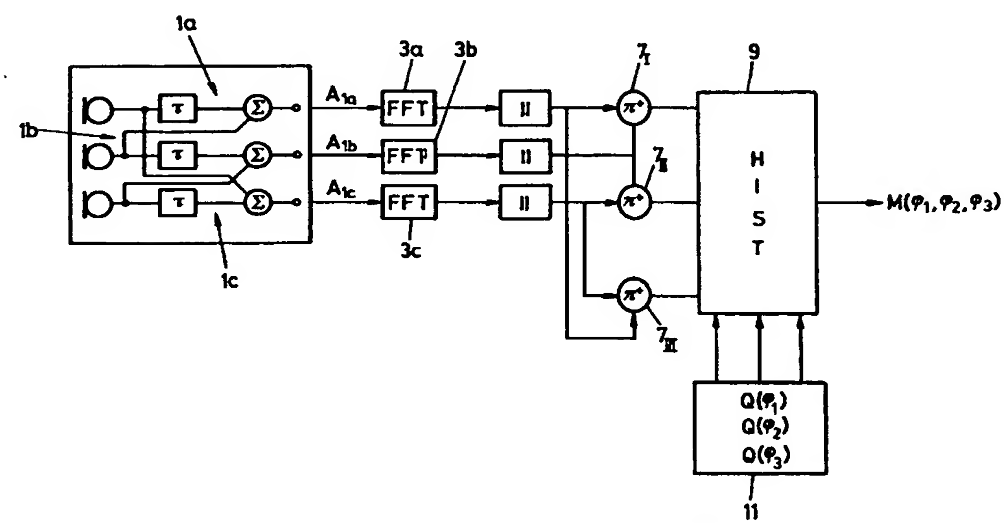

(57) Abstract: The invention relates to a method for localising sources of electromagnetic or acoustic signals in relation to a sensor arrangement (1a to 1c) with at least two electrical outputs. The two transmission functions, which are dependent on the direction of incidence, are different between the acoustic signals that are incident on the sensor arrangement (1a to 1c) on the input side and the electrical output signals. According to the invention, the quotient (7_I to 7_{II}) of the output signals is formed and the result is then correlated with the previously determined quotient function (11).

(57) Zusammenfassung: Zur Ortung elektromagnetischer oder akustischer Signalquellen bezüglich einer Sensoranordnung (1a bis 1c) mit mindestens zwei elektrischen Ausgängen, wobei die einfallsrichtungsabhängigen Übertragungsfunktionen zwischen eingangsseitig auf die Sensoranordung (1a bis 1c) einfallenden akustischen Signalen und elektrischen Ausgangssignalen unterschiedlich sind, wird der Quotient (7_I bis 7_{II}) der Ausgangssignale gebildet, das Resultat anschliessend mit der vorab bestimmten Quotientenfunktion (11) korreliert.

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Zur Erklärung der Zweibuchstaben-Codes, und der anderen Abkürzungen wird auf die Erklärungen ("Guidance Notes on Codes and Abbreviations") am Anfang jeder regulären Ausgabe der PCT-Gazette verwiesen.

METHOD FOR LOCALISING DIRECTION AND LOCALISATION ARRANGEMENT

The present invention relates to a method for directionally locating a source of electromagnetic or acoustic signals according to the precharacterizing clause of claim 1 and to an arrangement for this according to the precharacterizing clause of claim 6.

The insights leading to the present invention were acquired from needs relating to the directional location of acoustic sources. Accordingly, the present description of the invention will also be concerned mostly with the directional location of acoustic sources. Nevertheless, a person skilled in the art readily appreciates that the present invention is entirely suitable for being extended to the locating of electromagnetic signal sources. The question as to which kind of sources are to be located only affects the kind of sensors used according to the invention. In the special case of locating acoustic signal sources, the sensor arrangement is an arrangement of microphones, whereas when locating electromagnetic sources it is an arrangement of antennas followed by antenna boosters.

For the locating of such sources, in particular in an environment in which a number of sources are active at the same time, procedures which are mathematically complex or demand substantial equipment are presently known. If in this case less equipment is used by reducing the number of sensors provided, the mathematical complexity relating to source-locating discrimination will in turn increase. For locating acoustic signal sources, the ascertainment of phase differences between acoustic signals simultaneously incident on the microphones of the microphone

arrangement will be taken as a basis here by way of example.

It is an object of the present invention to propose a directional locating method and a corresponding arrangement, by means of which the demands and requirements mentioned are drastically reduced.

Taking a method of the kind mentioned at the beginning as a basis, this is achieved by implementing it in the way specified by the characterizing clause of claim 1.

If a sensor arrangement with at least two electrical outputs is provided, with different transmission characteristics, in terms of the dependence of the electrical output signals on the direction of incidence of the input signals, being effective between the electromagnetic or acoustic input and the at least two electrical outputs mentioned, in the form of reception lobes, it has been observed that, by forming the quotient for signals which represent the output signals mentioned, a quotient function which is unambiguous for a locating angle of a source and is independent of the signal level is formed. Consequently, in the minimal configuration of the procedure proposed, a locating angle is unambiguously ascertained, and it is this procedure which provides the basis for ascertaining two locating angles per source and consequently spatially finding out the source location unambiguously in the form of a locating beam and/or, when there are a number of sources active at the same time, locating them at least within the one locating angle mentioned. As still to be explained, the quotient forming mentioned directly produces for the source location a locating cone, the aperture angle of which is ascertained as a locating coordinate.

Unambiguous directional location of a source, i.e. locating of a locating beam for the source, becomes possible by evaluating at least three of the quotients mentioned, for which purpose, as implemented in a preferred embodiment, at least three of the electrical outputs are provided, assigned to which are respectively different transfer functions of the aforementioned kind, i.e. in the form of different receiving characteristics.

If the procedure previously discussed is used in an environment with only a single active signal source, said source is located. If, however, a number of signal sources are active at the same time, an actual spectrum of locating angles is produced, and a single measurement does not immediately reveal how many sources are active and from which locational direction.

For this purpose, it is proposed in a further preferred embodiment that the quotient forming mentioned is performed at several staggered times and the quotient results are used to create a histogram function, which is correlated with the previously determined quotient/direction-of-incidence dependencies and used to ascertain the locational direction of the at least one source.

This procedure is preferably used both for implementing the procedure according to the invention with at least two of the outputs mentioned and for implementing it with at least three of the outputs mentioned.

In the proposed histogram function, electromagnetic or acoustic signals generated by sources which are active for some time result in the same quotient values, which is reflected by these values being accumulated in the

histogram function set up. When correlated with the previously determined quotient/direction-of-incidence dependence mentioned, these accumulated values lead directly to ascertainment of the respective at least one locating angle of the signal sources active in the field.

In a further preferred embodiment, the output signals of the sensor arrangements mentioned are evaluated in the frequency domain. Considering that the transmission characteristics mentioned change with the signal frequency only within the rolloff range, it follows that the effect of the frequency will be eliminated when forming the quotient, in particular whenever the selected transmission characteristics have the same rolloff behavior. Therefore, the signal evaluation in the frequency domain not only makes it possible to set up the histogram mentioned from time-staggered measurements, but also from the spectral quotient results simultaneously ascertained in the frequency domain.

Transmission characteristics assigned to the respective electrical outputs which differ merely by a solid-angle phase shift, i.e. that "look" in a different direction but are otherwise identical, are preferably chosen.

An arrangement of the aforementioned kind according to the invention is distinguished according to the characterizing clause of claim 6, with preferred embodiments according to claims 7 to 10. The method according to the invention and the arrangement according to the invention are suitable in particular also for the locating of acoustic sources and, on account of the lower requirement for equipment and

computing power, in particular for implementation in the case of hearing devices.

The invention is subsequently explained by way of example on the basis of figures, in which:

figures 1a, 1b show transmission characteristics used in preference according to the invention for the locating of acoustic sources in the case of two submicrophone arrangements that are provided, in a minimal configuration;

figure 1c shows the common spatial orientation of the transmission characteristics for submicrophone arrangements as shown in figures 1a and 1b;

figure 2 shows, plotted against the one solid angle φ, as shown in figures 1a to 1b, the absolute value of the respective transmission characteristic and of the quotient function;

figure 3 shows, plotted against the solid angle φ, enlarged, the quotient function as shown in figure 2 to explain the correlation of ACTUAL value measurement and previously known dependence between quotient and angle φ;

figure 4 shows as an example a histogram function, formed on the basis of quotient results ascertained at staggered times;

figure 5 shows, on the basis of a simplified signal-flow/functional-block diagram, a locating arrangement designed according to the

invention and operating on the basis of the method according to the invention for acoustic signal sources, in a preferred embodiment;

figure 6a shows the locating position for a signal source, as ascertained by the procedure according to the invention or arrangement according to the invention in the minimal configuration;

figure 6b shows two locating beams, as ascertained in a development of the invention, and

figure 6c shows the ascertainment of the one locating beam, as ascertained in a further preferred embodiment of the invention.

The procedure according to the invention is to be presented by means of figures 1 to 4 without claim to scientific exactitude, on the basis of simple transmission characteristics, corresponding to first-order cardioids. This clear, simple procedure described below instructs a person skilled in the art how according to the invention it is possible even on the basis of quite complex transfer functions for one or more acoustic sources to be located according to the invention.

A first submicrophone arrangement - generally a sensor arrangement - of a microphone arrangement or sensor arrangement provided is assumed to have the three-dimensional transmission characteristic represented two-dimensionally in figure 1a as the transmission or amplification characteristic of signals incident on it with respect to direction φ.

In a representation analogous to figure 1a, figure 1b shows the transmission characteristic of a second sensor arrangement, which is assumed to be the mirror image with respect to the axis $\pi/2$; $3\pi/2$ of the transmission characteristic of the first sensor arrangement. The transmission characteristic as shown in figure 1a is denoted by c_N, that as shown in figure 1b by c_Z. Figure 1c shows the transmission characteristics c_N and c_Z simultaneously, as they present themselves with respect to the transfer functions on a sensor arrangement with correspondingly two subsensor arrangements and two electrical outputs. As mentioned, for locating acoustic sources, the arrangements are microphone arrangements.

In figure 2, the absolute value of the transmission characteristics c_N and c_Z is shown in dB, plotted against the angle axis φ as shown in figures 1a to 1c.

If unitary signals are incident on the two subsensor arrangements, the transmission characteristics represented in figures 1a and 1b simultaneously correspond to the respective signal values on the output side of the sensor arrangement being considered. According to the invention, the absolute-value quotient is then formed from these two output signal values, which are likewise denoted by c_N and c_Z, namely

$$Q = \left|\frac{C_N}{C_Z}\right| .$$

This quotient forming produces the function Q qualitatively represented in figure 2 by dash-dotted lines, with a pole at $\varphi = \pi$. In figure 3, the quotient function $Q(\varphi)$ is plotted once again between $\varphi = 0$ and $\varphi = \pi$.

It should be noted that, when forming the quotient Q, which for reasons of clarity has first been explained on the basis of unitary signals, the respective absolute values of the input signals cancel out by division, so that the angle dependence shown in figure 3 applies to arbitrary signals incident at φ on the sensor arrangement.

If this function is then measured and stored and, as schematically represented in figure 3, the instantaneous quotient function Q_{INS} is formed from an instantaneously incident signal INS, again represented in dB, the dB value found can be correlated with the stored quotient function $Q(\varphi)$, i.e. it can be entered with the found quotient value into the previously stored function or dependence $Q(\varphi)$: the locating direction φ_{INS} of the instantaneously incident acoustic signal is ascertained.

As readily inferred from consideration of figure 3 and, for example, figures 1a and 1b, the quotient function $Q(\varphi)$ is unambiguous from 0 to 180°, though only in the two-dimensional sectional plane through the spatial transfer functions represented in figures 1a and 1b. A locating angle φ which corresponds to a locating cone entered by dash-dotted lines in figure 1a for the aperture angle φ depicted there is found.

If it is wished to perform location unambiguously, at least three of the subsensor arrangements mentioned are to be provided, and correspondingly a sensor arrangement with three outputs. Forming the quotient in the way described, and the correlation with the respectively pre-recorded dependencies $Q(\varphi)$, takes place in pairs on two, preferably three, of the three output signals of the arrangement.

Although the locating information ascertained so far reveals that, at the present instant, an acoustic signal [lacuna] from the locating direction mentioned, whether this is established for two subsensor arrangements corresponding to a locating cone or for more than two sensor arrangements spatially by means of two or one locating beam, this only reveals that, at the present instant, an acoustic signal is incident from the direction mentioned. Consequently, a located acoustic signal source is active at the present instant.

However, to obtain information on the location of an acoustic source active over an extended period of time as distinct from stochastically distributed acoustic signals incident from different directions, the procedure then followed in principle is to observe from which locating direction there is an accumulation of incident signals over the time period, allowing the conclusion that an acoustic signal source is located there.

For this purpose, the quotient Q_{INS} mentioned is repeatedly formed from the output signals and used to form a histogram, as shown by way of example in figure 4. For this purpose, the frequencies are recorded specific to quotient values (as shown in figure 4 in dB). Figure 4 shows in this respect an example of a histogram recorded in this way, with the frequency n of quotient values that occurred. The inference is that, according to the accumulation at about -38 dB and -20 dB as shown in figure 3, an acoustic source is active in the direction $\varphi \cong 15°$ and one at $\varphi \cong 35°$.

The proposed procedure is in this case eminently suitable for implementation in the frequency domain. If it is taken into consideration in this respect that the transmission characteristics in each case change frequency-dependently in a similar manner on account of the frequency rolloff, as shown for example in figures 1a and 1b, it is evident that the quotient function mentioned is frequency-independent. Consequently, the output signals of the sensor arrangement can be converted consecutively several times into the frequency domain and the quotient forming mentioned, which contains the same directional information independent of frequency, can be performed for a selected number of spectral amplitude values in the frequency spectrum.

With a number N of subsensor arrangements, in particular microphone arrangements, it is possible by the proposed method to locate a possibly substantially larger number M of signal sources, in particular acoustic signal sources. If in this case more than two subsensor arrangements are used, there is a possibility of carrying out unambiguous spatial location. It is for example also evident from the distribution from figure 4 that, in the locating angle range between 110° and 130°, it is highly probable that two or more approximately identical sources are active.

In figure 5, a locating arrangement operating by the method according to the invention is represented on the basis of a simplified signal-flow/functional-block diagram using the example of a locating arrangement for acoustic signals. It is suitable in particular also for use on a hearing device.

The arrangement according to the invention comprises a microphone arrangement 1 with at least two submicrophone arrangements 1_x, as shown preferably with three submicrophone arrangements 1b - 1c, which are each led to corresponding outputs A_{1a} to A_{1c}. The three submicrophone arrangements have different transmission characteristics, for example correspondingly first-order cardioids pointing in different directions, which is implemented for example and by preference by the submicrophone arrangements being set up with two microphones of which the outputs are coupled to each other by the "delay and add" technique. By providing the three submicrophone arrangements, a third cardioid is created, making it possible for two or three quotients to be formed at the same time and as still to be explained. Consequently, two locating cones as shown in figure 6b or three locating cones as shown in figure 6c are ascertained. With two locating cones, in each case a source is still ambiguously located, with three it is unambiguously located.

In a preferred embodiment, the output signals A_{xy} are converted into the frequency domain at time-domain/frequency-domain converter units FFT 3a to 3c. The outputs of the time-domain/frequency-domain converter units 3a to 3c are operatively connected in pairs, for example as represented in each case via absolute-value forming units to numerator or denominator inputs of three quotient-forming units 7_I to 7_{III}. The outputs of the quotient-forming units 7_I to 7_{III} are operatively connected to an evaluation unit 9, at which, as explained, in particular the histograms are formed. In order to implement the correlation of the found quotient-value distribution with the quotient/locating-angle dependence, the dependencies $Q(\varphi_1)$ to $Q(\varphi_3)$ are additionally fed to the evaluation

unit 9, as schematically represented in figure 5. These dependencies were measured or calculated beforehand on the basis of the sensor arrangement 1 provided in the given case and are stored, in schematic form, in the function memory unit 11. In this case, φ_1 to φ_3 denote the locating cone aperture angles as shown in figures 6a to 6c. By appropriate conversion in the evaluation unit 9, i.e. evaluation of the histogram distribution and assignment of its peak values to the corresponding locating angles φ_1 to φ_3, then appropriate conversion according to the desired locating coordinates, the number of detected acoustic sources M with their locating angles are output on the output side of the evaluation unit 9.

The proposed procedure is eminently suitable for implementation in hearing devices and can form the basis for directing the directional characteristic of a hearing device to detected sources, or - if these are defined or found to be sources of interference - for setting up a high attenuation of the transmission characteristic in the locating direction mentioned.

In principle, all known microphones or sensors and their combinations, having different transmission characteristics as required in the operational position and as required with respect to the direction of incidence φ of incident acoustic signals, can be used as submicrophone arrangements or subsensor arrangements.

However, especially for implementation which is simple and easily monitored, it is proposed to use identical subsensor arrangements, the transmission characteristics of which are indeed identical but

spatially directed differently with respect to axial alignment (in figure 1a corresponding to $\varphi = 0$).

With the procedure according to the invention it is possible without determining signal phases or signal time delays and without using correspondingly complex logarithmation of complex variables to locate signal sources in an exceedingly simple manner by quotient forming and subsequent simple evaluation in the environment, in particular acoustic sources in the acoustic environment.

Patent claims:

1. A method for directionally locating a source of electromagnetic or acoustic signals with respect to a sensor arrangement with at least two electrical outputs, the transfer functions, dependent on the direction of incidence, between acoustic signals incident on the input side of the sensor arrangement and electrical output signals at the two electrical outputs being different, characterized in that a quotient (Q_{INS}) is formed from signals which represent the output signals of the sensor arrangement and at least one locating direction of the source is determined from correlation of the quotient result with the previously determined dependence of the quotient ($Q(\varphi)$) on the direction of incidence (φ).

2. The method as claimed in claim 1, characterized in that the sensor arrangement has at least three of the outputs and the quotient forming and correlation is performed on signals which are representative of the electrical signals at at least two, preferably at three, pairs of the at least three electrical outputs.

3. The method as claimed in either of claims 1 and 2, characterized in that the quotient forming is performed several times and the results are used to create a histogram function, which is correlated with the previously determined quotient/direction-of-incidence dependence and used to ascertain the locational direction of the at least one source.

4. The method as claimed in one of claims 1 to 3, characterized in that the signals at the output of

the sensor arrangement are fed to the quotient forming in the frequency domain.

5. The method as claimed in one of claims 1 to 4, characterized in that transmission characteristics which define different spatial reference angles, but in this respect are at least approximately identical, are created.

6. An arrangement for directionally locating sources of electromagnetic or acoustic signals, with a sensor arrangement (1) with at least two electrical outputs (A_{xy}), the sensor arrangement having different transfer functions, with respect to the direction of incidence of the signals, between incident electromagnetic or acoustic signals and the outputs (A_{xy}), characterized in that at least one quotient-forming unit (7) is operatively connected to the at least two outputs (A_{xy}) of the sensor arrangement (1), which unit is operatively connected on the output side to at least one input of an evaluation unit (9), at the output of which a signal (M) identifying at least one locating direction (φ_1) of the source is generated.

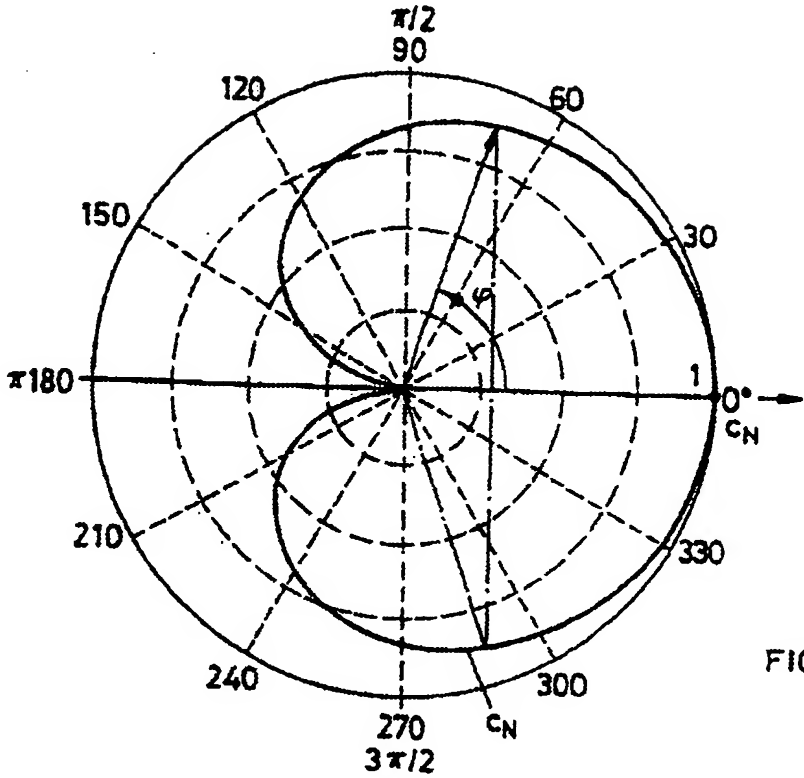
7. The arrangement as claimed in claim 6, characterized in that the sensor arrangement (1) has at least three of the outputs (A_{xy}) and in that these outputs are operatively connected in pairs to at least two, preferably to three, quotient-forming units (Q_I - Q_{III}).

8. The arrangement as claimed in either of claims 6 and 7, characterized in that a time/frequency-domain converter unit (3) is interposed between the

outputs (A_{xy}) of the sensor arrangement (1) and the inputs of the quotient-forming unit (Q).

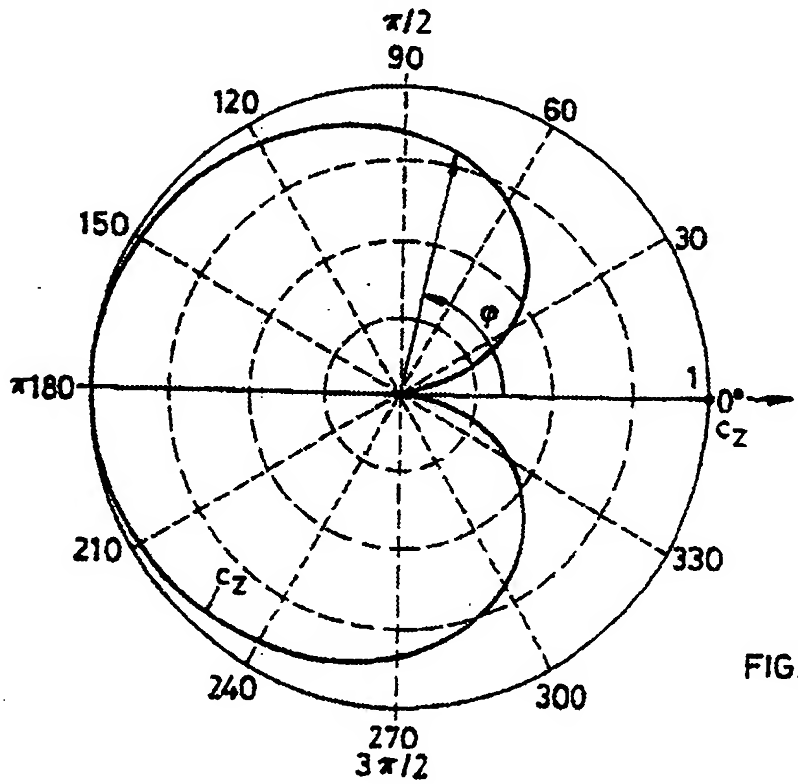
9. The use of the method as claimed in one of claims 1 to 5 or the arrangement as claimed in one of claims 6 to 8 for the locating of acoustic sources.

10. The use as claimed in claim 9 on hearing devices.



π/2
90
120
60
150
30
φ
π180
1
0°
c_N
210
330
240
300
270
3π/2
c_N

FIG.1a



π/2
90
120
60
150
30
φ
π180
1
0°
c_Z
210
330
c_Z
240
300
270
3π/2

FIG.1b

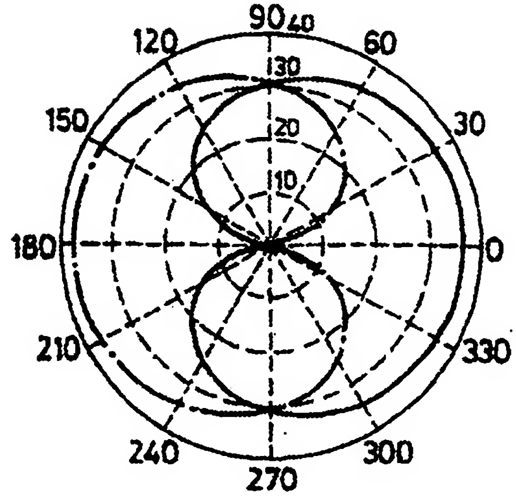

90
40
120
60
30
150
30
20
10
180
0
210
330
240
300
270

FIG.1c

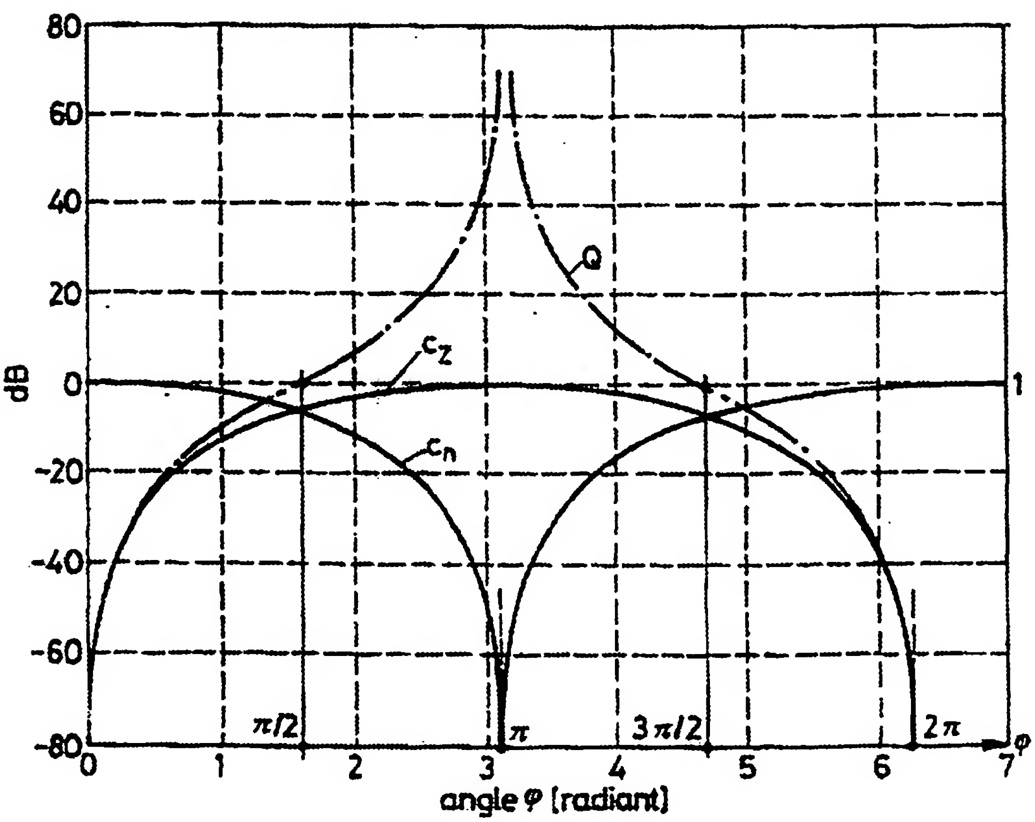

80
60
40
20
0
-20
-40
-60
-80
dB
Q
c_z
c_n
1
$\pi/2$
π
$3\pi/2$
2π
φ
0
1
2
3
4
5
6
7
angle φ [radiant]

FIG.2

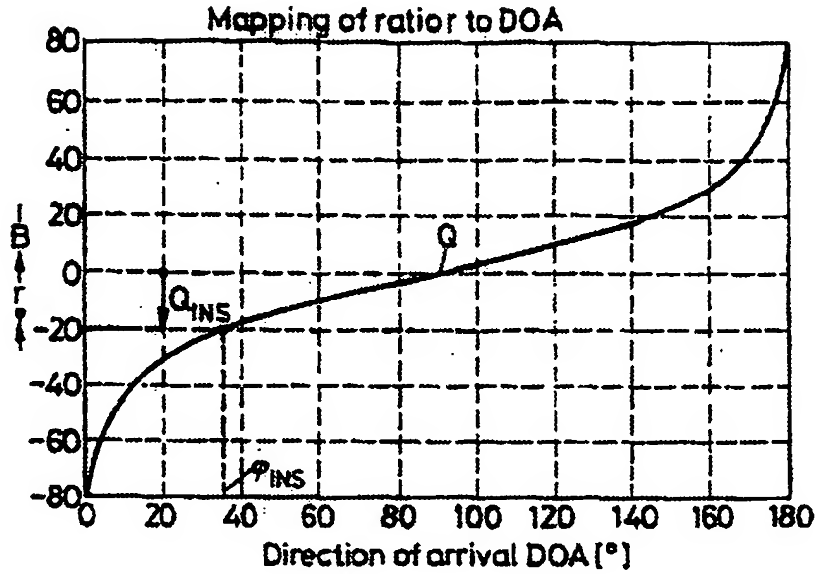

Mapping of ratio r to DOA
80
60
40
20
0
-20
-40
-60
-80
r → dB
Q
Q_{INS}
φ_{INS}
0
20
40
60
80
100
120
140
160
180
Direction of arrival DOA [°]

FIG.3

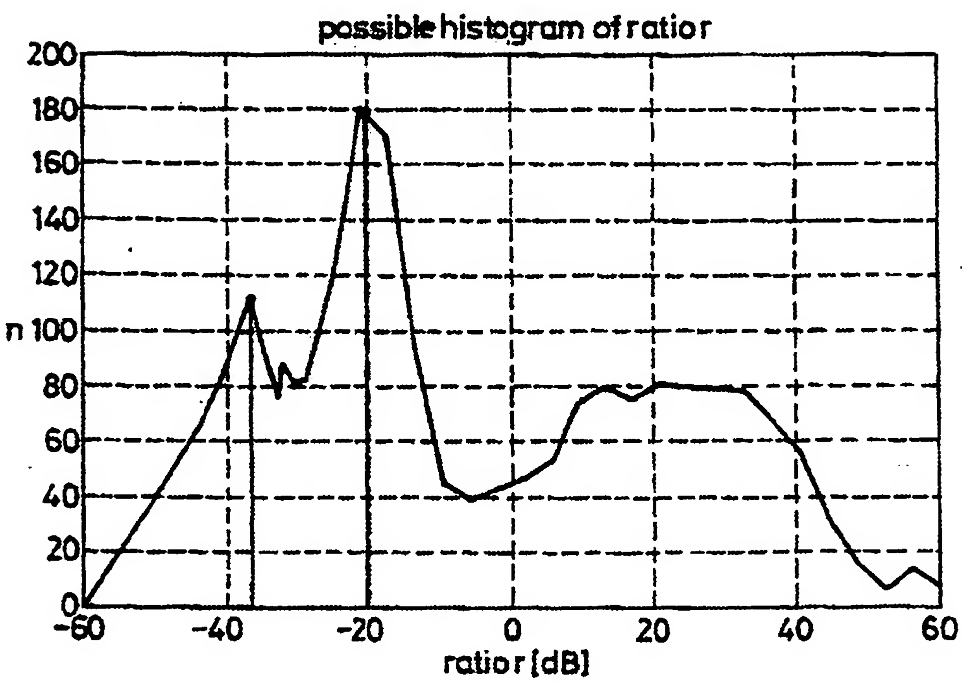

possible histogram of ratio r
200
180
160
140
120
n 100
80
60
40
20
0
-60
-40
-20
0
20
40
60
ratio r [dB]

FIG.4

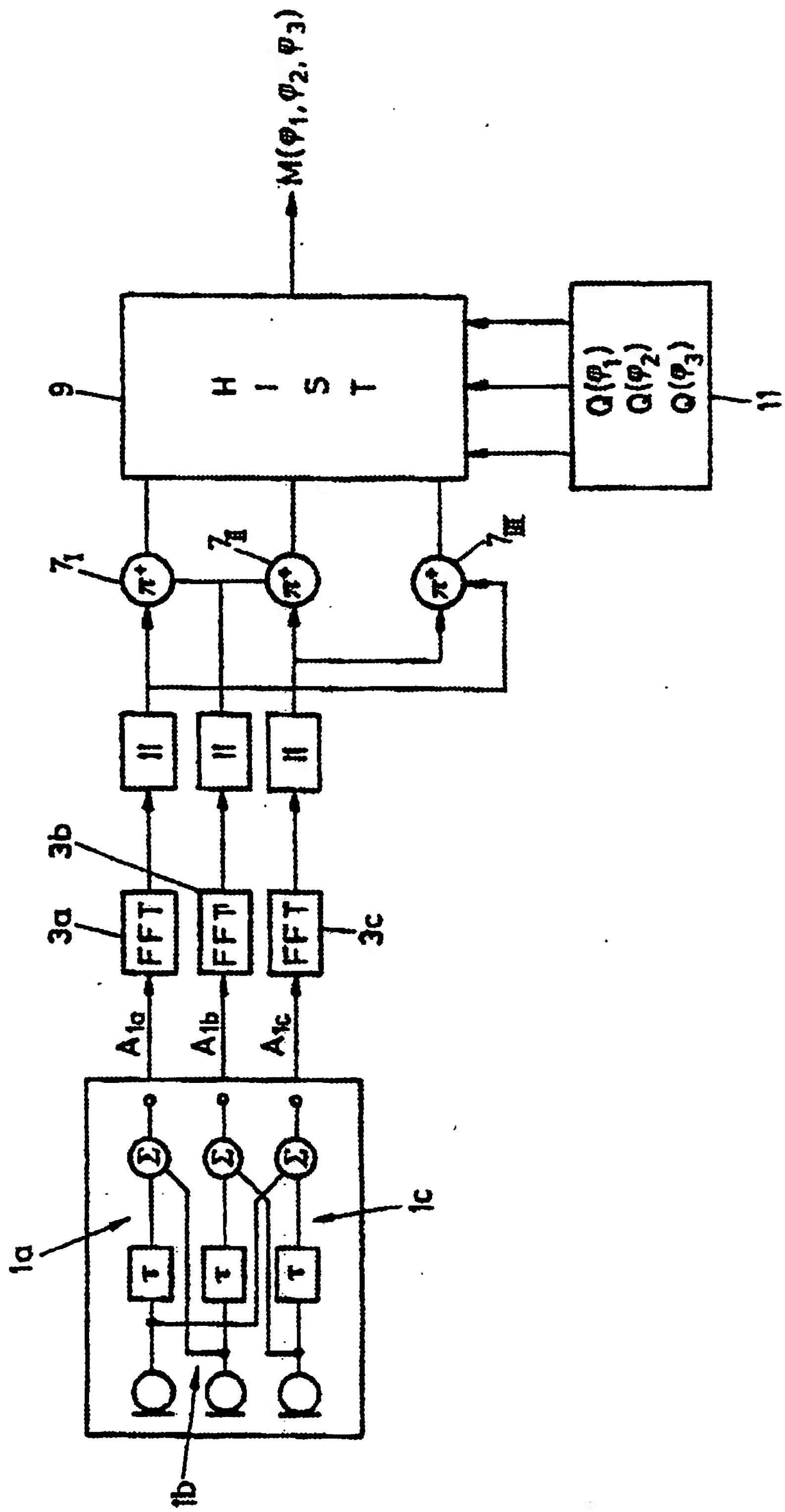

M(φ1, φ2, φ3)
9
HIST
Q(φ1)
Q(φ2)
Q(φ3)
11
7I
7II
7III
3a
3b
3c
FFT
FFT
FFT
A1a
A1b
A1c
1a
1b
1c

FIG.5

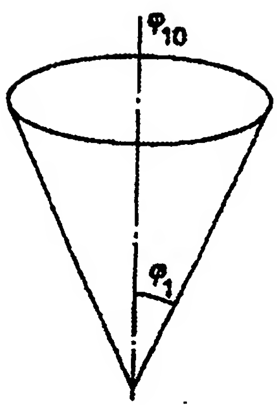


FIG.6a

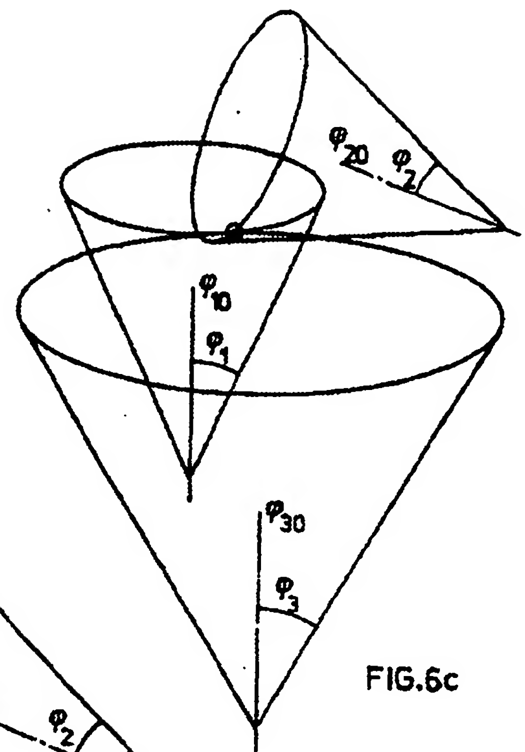


FIG.6c

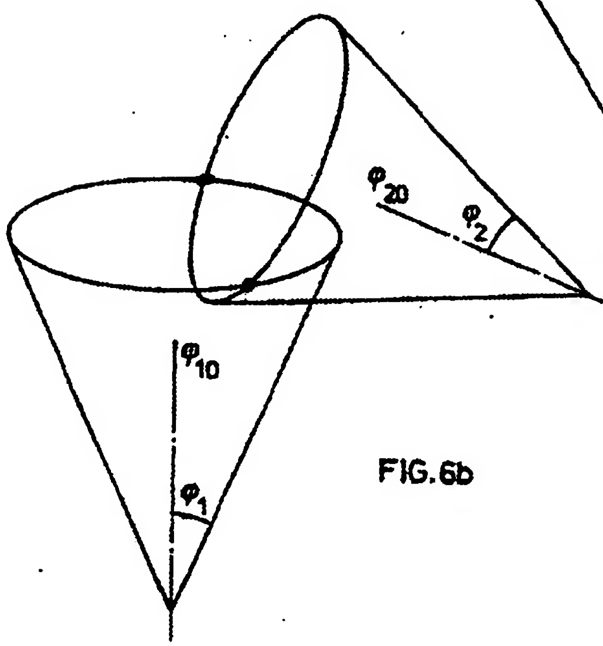
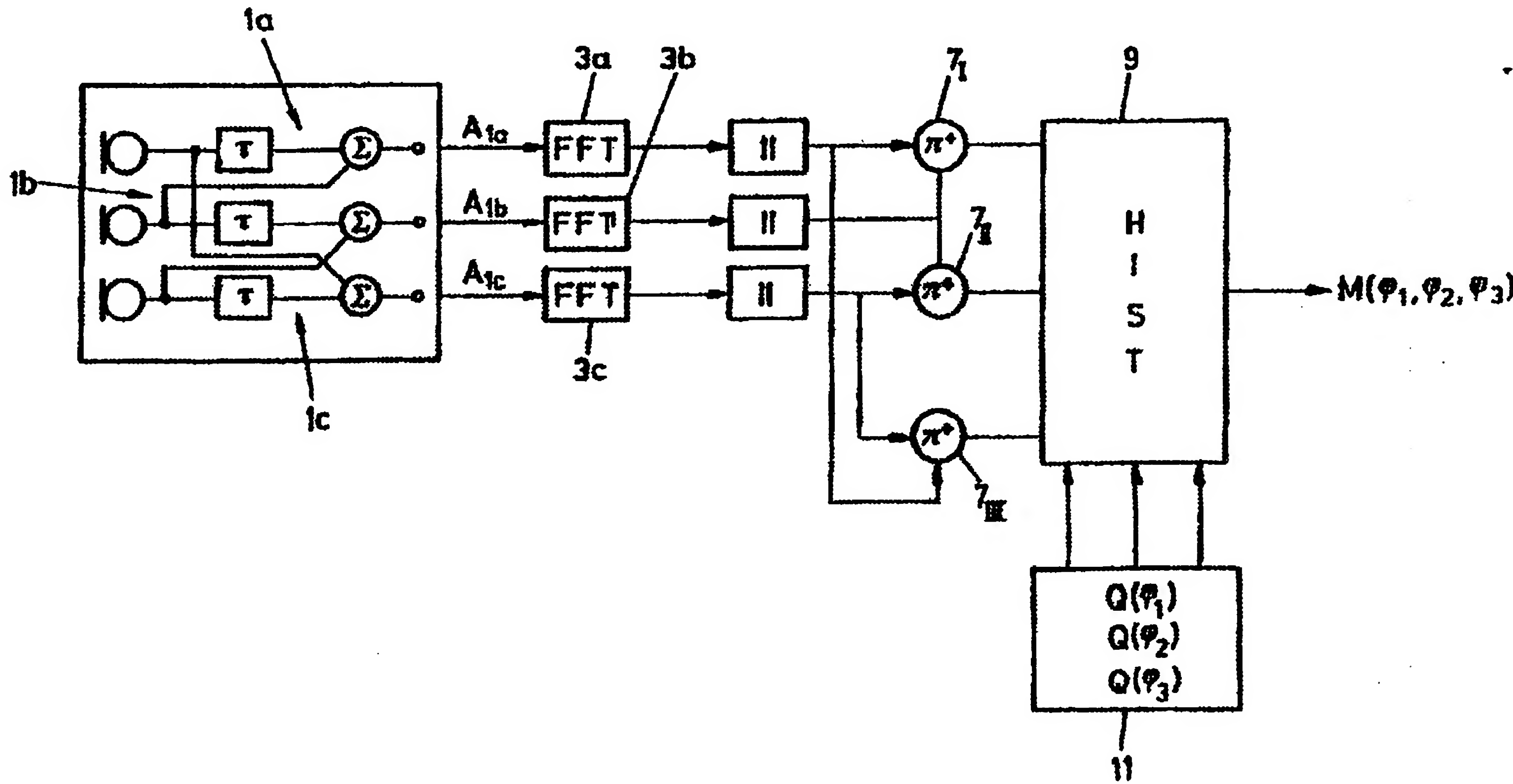


FIG.6b


1a
1b
1c
τ
Σ
A1a
A1b
A1c
3a
3b
3c
FFT
7I
7II
7III
π+
9
HIST
M(φ1, φ2, φ3)
Q(φ1)
Q(φ2)
Q(φ3)
11